

Exposure Control in a Multi-Stage Photographic System

Abstract: The use of controlled exposure in microfilming original documents offers a practical method for producing high-contrast images at subsequent printing stages with constant exposure times. This type of control, used for the three-stage generation of images in a developmental photo-image retrieval system, has given excellent results for documents which have uniform line-density contrast. For variable contrast documents, an analysis of the variations and variable exposures used in microfilming is necessary. The details of the analysis are described in this paper.

Introduction

Rudd¹ and others²⁻⁴ in their papers on microfilm exposure control proposed a single best-exposure time for photographing original documents having a range of contrast values. More recently, however, Vyverberg⁵ showed that, if the original documents have a wide range of contrast, there is no single value of either line density or background density to which the microfilm can be exposed to obtain high-contrast reproduction with constant exposure at a subsequent printing stage. Rather, he found that, to produce Xerox* copies from microfilm at a constant exposure, it was necessary to vary the microfilm exposure. That is, the lower the contrast on the original document, the higher the line density and the lower the background density on the microfilm must be; the converse is also true. It was actually Vyverberg's conclusions that served as a major impetus to the work reported in this paper.

Normally, original documents are first microfilmed on a silver halide film. In many cases the microfilm may then be mounted in an aperture card which serves as an archival storage medium. The working file may be a diazo copy of the original microfilm. Copies for distribution to users are third-generation copies, contact printed on diazo material from the diazo file copy.

Since the original drawings whose images are to be stored in a multigeneration photographic system may be of varying quality, the problem becomes one of determining whether proper control over the exposure of the input microfilm would permit constant exposure times at the subsequent printing stages. The general approach that we de-

vised is to measure the differences in density (line contrast) between the lines and background on the drawing being microfilmed, and then to expose the microfilm until the lines have a density which will produce maximum contrast between lines and background on the diazo file and output materials at constant exposure times. The exposure times for these two photographic generations may be predetermined since they are functions of the respective characteristic curves of the diazo photomaterials.

We have found that, for all standard, "off-the-shelf" diazo photo materials, there is one practical control point, the quarter density point of the photomaterials; that is, $\frac{1}{4} (D_{\max} - D_{\min}) + D_{\min}$. For the general case of any photomaterial, this point is the inflection point of the Hurter-Driffeld (H & D) curve for the material. The use of the control-point method gives accurate results when the following conditions are assumed:

- The line and background densities vary from original drawing to original drawing but are uniform on any given drawing.
- The lines on any drawing are sufficiently wide so that the resultant line contrast on the diazo material is independent of line width.
- The shape of the characteristic curve which describes the density vs log exposure time of the diazo material is independent of the variation in spectral properties due to non-uniform wavelength absorbance characteristics of the silver and diazo films.

* Trade name, Xerox Corp., Rochester, N. Y.

For a proper understanding of the discussion which follows, two terms must be defined: line contrast and systems printing density.

- Line contrast is the background density minus line density.
- System printing density of a print-through photomaterial to a receptor photomaterial is defined as the equivalent log exposure light attenuation (neutral with respect to wavelength) caused by the print-through photomaterial absorbing light. All densities used in plots and discussion are systems printing densities to the next generation photomaterial or photoreceiver.

A method will now be shown by which the correct values for the line densities on the input microfilm are derived for documents having uniform line-density contrast within themselves. This will be followed by a brief description of the same analysis for the exposure of file diazo material. Finally, an approach will be given for analyzing the variations and variable exposures used in microfilming variable contrast documents.

Exposure of input microfilm

The exposure characteristic of photomaterials is conventionally given by the H & D curve, which is a plot of the density of the exposed surface of the material as a function of the $\log_{10}$ of the time the material is exposed to light. If a translucent material having uniform absorption in the given wavelength region is inserted between the light source and the photomaterial, the shape of the H & D curve remains the same, but the curve is translated along the time axis an amount that depends on the density of the inserted material. Figure 1 shows the H & D curve of a typical diazo material (P8-310) used for storage in a three-stage image-generation system. It also shows that the curve is translated 0.1 units along the log exposure time axis for every 0.1 density units increase of an intervening silver microfilm. (Note that these curves are plotted in terms of the system printing density of the file diazo material to the output diazo material.)

Now, pick two values of microfilm density; i.e., consider two of the curves on Fig. 1. Call the smaller value "line density" (if the microfilm is a negative image), the larger value "background density," and their difference "line contrast." Then, for this given value of microfilm line contrast, a plot of diazo contrast can be made by recording the vertical distance between the two selected curves as a function of log exposure time. Figure 2, a set of curves derived from Fig. 1, shows diazo line contrast as a function of log exposure time for a number of microfilm line contrast values, all based on a microfilm line density of 0.0.

The need to vary the exposure on the microfilm can be seen from a study of these curves. Note that the maximum

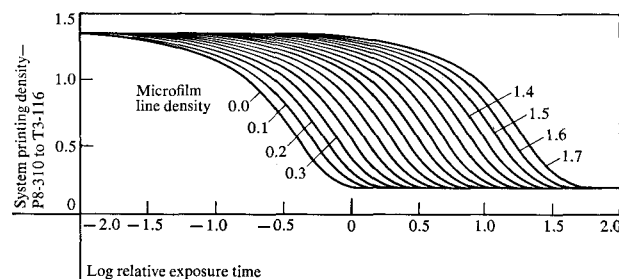


Figure 1 Printing characteristic curves for P8-310 diazo after printing through a series of printing density steps of silver microfilm.

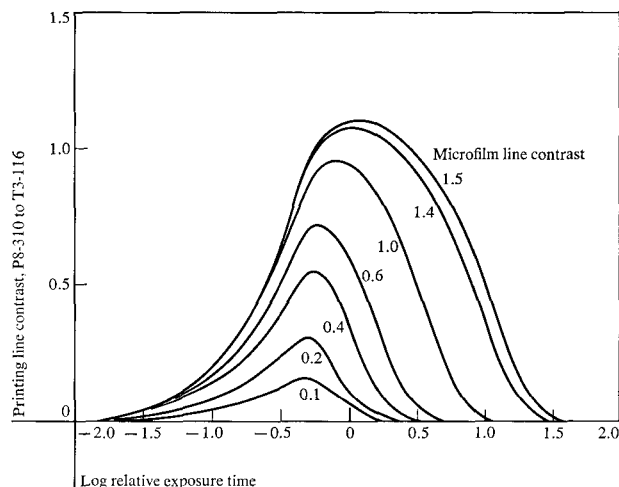


Figure 2 Derived P8-310 diazo line contrasts as a function of log relative exposure time.

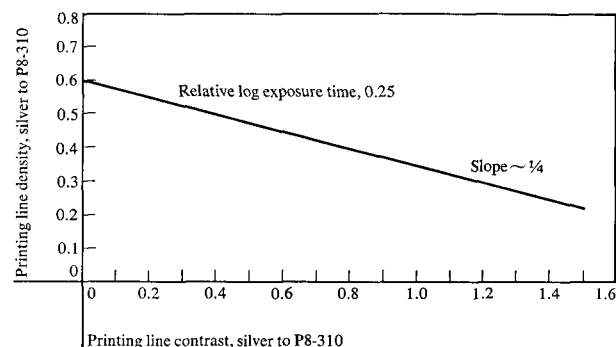
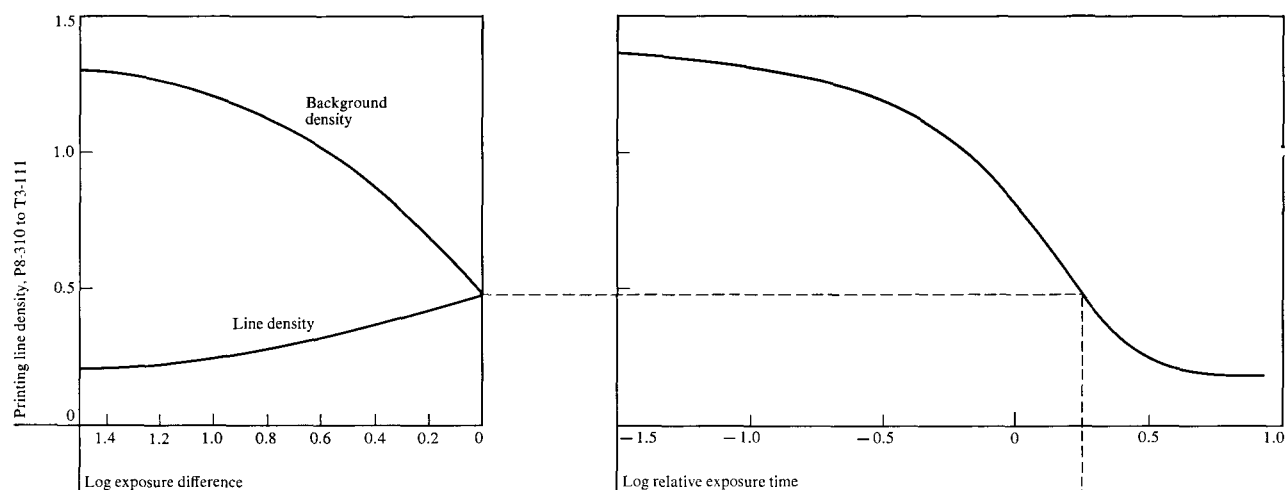


Figure 3 Printing line density of silver microfilm as a function of printing line contrast of the silver.

diazo contrast for each value of microfilm contrast occurs at a different log exposure time. Since we wish to make the maximum occur at the same time for all microfilm contrasts, each curve must be shifted some distance along the log exposure time axis.

If we arbitrarily select 0.25 as the constant value of log exposure time (this is approximately 1.78 sec with a typical light source and optics), then the amount of shift is simply



0.25 minus the log exposure time at which the maximum diazo contrast occurs. For example, the curve for a microfilm line contrast of 0.4 must be shifted 0.5 units if the peak is to occur at a log exposure time value of 0.25. As mentioned above, this amount of shift corresponds to an increase of microfilm line density from 0.0 to 0.5.

So, from Fig. 2, we can obtain the data to plot a curve of microfilm system print density vs microfilm line contrast (Fig. 3). If the microfilms are prepared such that their line densities have the values specified by Fig. 3, all images on the diazo file chips at a log exposure time of 0.25 will have maximum possible line contrast.

Figure 3 shows that a microfilm having a zero line contrast must be exposed to a line density of 0.6. Referring to the H & D curves in Fig. 1 for a microfilm density of 0.6, we see that the diazo file chip will be printed with zero line contrast and a density of 0.47 at a log exposure time of 0.25. This density of 0.47 occurs at the inflection point of the H & D curve, which is a point 1/4 of the distance from the minimum to maximum density. This experimentally noted control point was later verified mathematically for standard diazo photomaterials.

Combining the curves of Figs. 1 and 2 produces a curve similar to Fig. 3 on which the density of diazo lines is plotted as a function of the diazo line contrast that results when the file chip is exposed for 0.25 log exposure time units. Line density of the file diazo chip as a function of line contrast (Fig. 4) has been replotted in Fig. 5. Note that the slope of this curve is again approximately 1/4, the same as the slope of the microfilm line density vs contrast curves. Thus, if we contact-print silver microfilm described by the relationship shown in Fig. 3 at the constant log exposure time of 0.25 unit, or to the inflection point (1/4 density point) of the file chip, we will obtain the maximum line contrast in the file diazo photomaterial and a resultant line density vs line contrast having the same slope as the one for the silver microfilm.

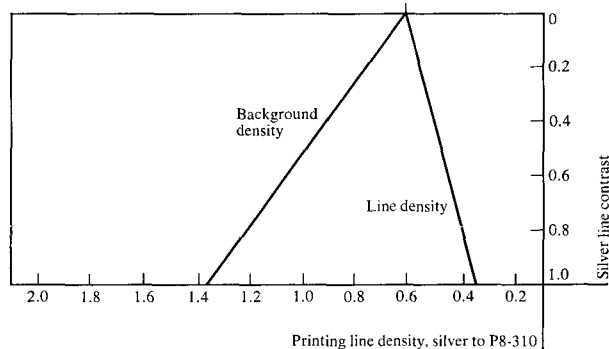
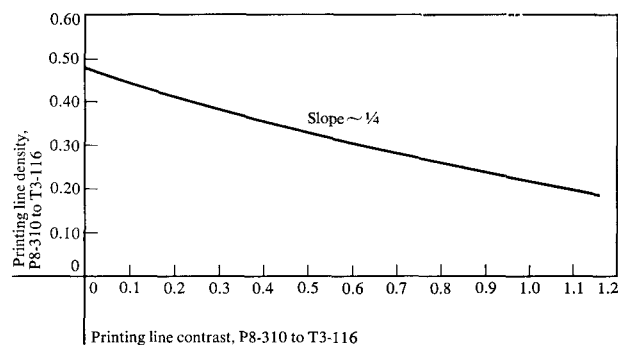


Figure 4 Transfer of silver input to P8-310 diazo.

Figure 5 Printing line density of P8-310 diazo as a function of printing line contrast of P8-310 diazo.



Exposure of file diazo material

Next, consider the stage of printing the file diazo material to the output diazo material. The output material may be T3-116 diazo, whose H & D characteristic is shown in Fig. 6. If we should go through the same analysis followed to determine the silver-film line density vs contrast curve with the diazo of Fig. 6, we would obtain a plot similar to Fig. 3, which again would have a slope of approximately 1/4.

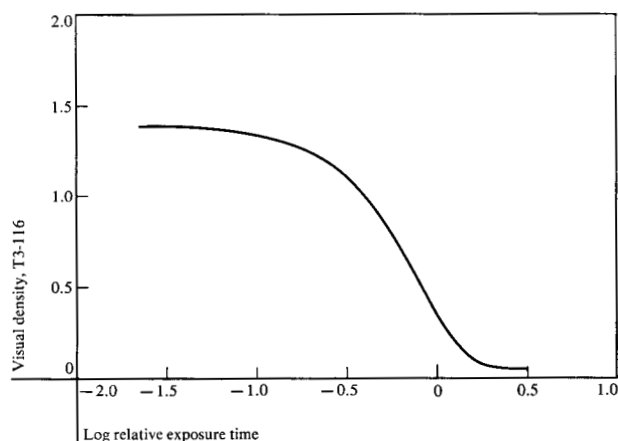


Figure 6 Visual density characteristic curve for T3-116 diazo.

Since the file chip (Fig. 5) does meet this requirement, the arbitrary exposure time selected for use in printing this file chip to the output aperture card to meet the maximum line contrast condition is obtained by determining the log exposure time required to print 0.47 density to the inflection point of the T3-116 output diazo photomaterial. Hence, again, we have a constant exposure time. This constant output exposure time is defined simply by connecting the two inflection points (or 1/4 density points) of the two diazo photomaterials in the file and output diazo (Fig. 7).

Nonuniform line contrast

As noted in our conditions for the above analysis, accurate results are obtained when the line contrast of the input drawing is uniform over the complete drawing. In reality, this uniformity will not always occur. Hence, there is the need for determining an optimum exposure time.

We performed an experiment to test the hypothesis that the optimum exposure time is the one which produces the highest sum of output-film contrast values for a set of input documents having a variety of contrasts. Three targets of the same pattern (low, medium and high contrast) were printed on the file diazo material at many different exposure times. For each time, the sum of the contrasts obtained on the file diazo for the three targets was computed and plotted as in Fig. 8. The time at which the sum was highest was judged to be "best."

The next step in the experiment was to determine if maximum contrast summation was obtained on the output diazo from a print of the file diazo having maximum contrast summation. And if it was, we wished to determine the best output exposure time to produce it. The file diazo image having maximum contrast summation was printed to the output diazo at a number of exposure times. Two other file

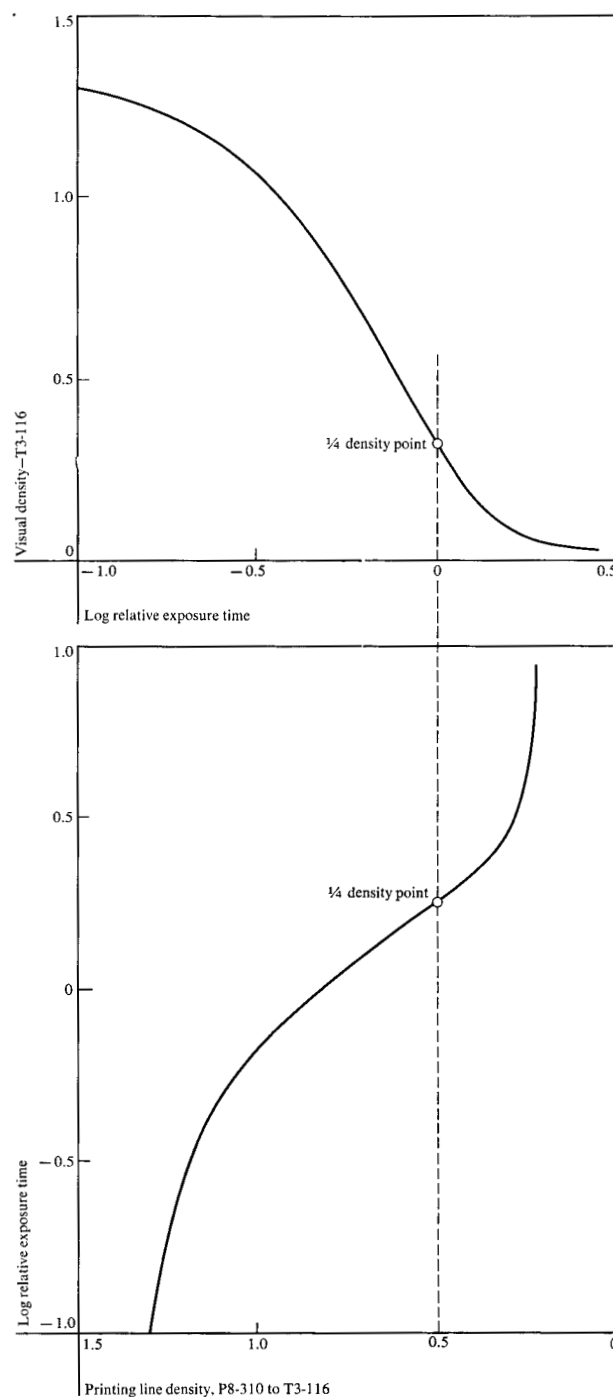


Figure 7 Exposure conditions for printing P8-310 diazo to T3-116 diazo.

images whose contrast summations were close to the maximum were also printed to the output diazo at the same exposure times. The summation of contrasts for each exposure was computed and plotted as before (Fig. 9). Best contrast results were obtained from the maximum contrast file chip, and the best exposure was obtained when the chip was

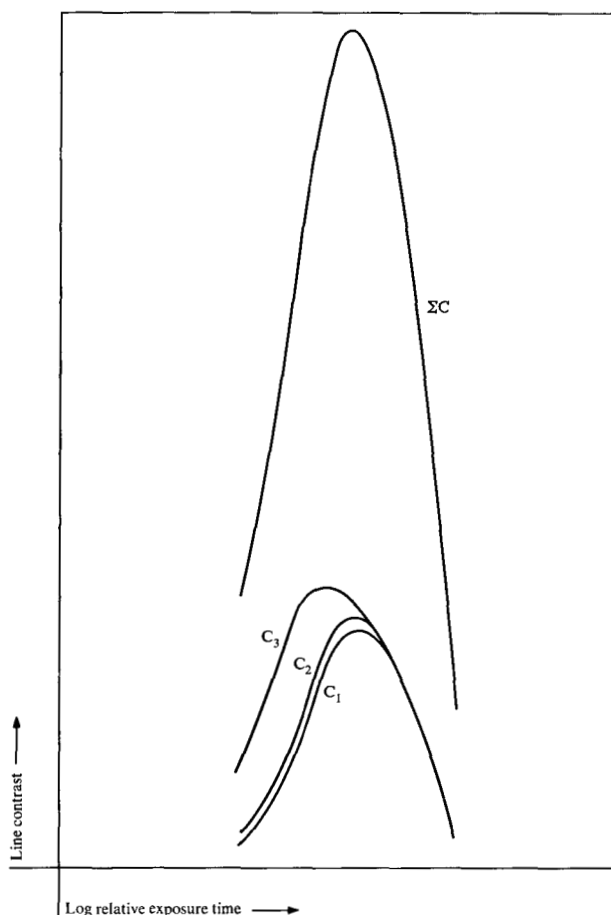


Figure 8 Summation of contrasts for three different contrasts of test targets.

printed to the output diazo at an exposure time determined by lining up the 1/4 density points of the file diazo and output diazo. This was the same constant exposure used for the preceding analysis when we had uniform drawing line contrast.

Conclusions

Controlling the exposure of input microfilm is feasible for producing high-contrast prints at subsequent printing stages with a constant exposure. Proper microfilm line density for a given line contrast has been derived for normal off-the-shelf diazos, and a method of determining the same for any photomaterial has been devised. While the proposed analysis gives precise results only if the original drawings have uniform line contrast, it is a good approximation to reality for drawings that have been prepared to meet high standards of line weight and line contrast.

If the original document does not have uniform line contrast and the contrast varies over a wide range in the resulting microfilm, the best microfilm-to-chip exposure time is a compromise. The compromise exposure time is the one which yields the greatest sum of contrasts in the file chip.

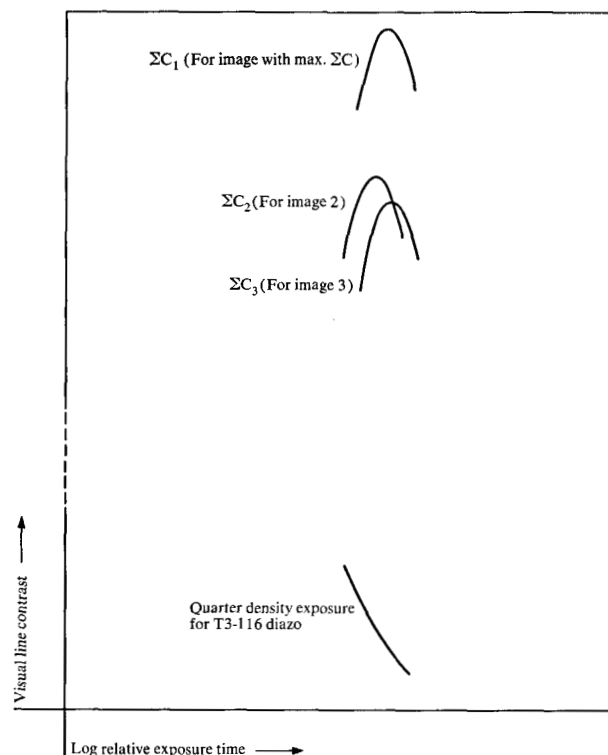


Figure 9 Exposure conditions for "best" output diazo results.

Once this optimum file chip exposure time is obtained, the best output exposure is the same as the one proposed for the uniform line contrast drawings, which is simply determined by connecting the 1/4 density points of the off-the-shelf diazos, or more precisely connecting the inflection points of the file and output photomaterials.

References

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